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A FINAL REPORT FOR THE PROJECT ENTITLED

Assessing the Impact of *Bacillus thuringiensis kurstaki* on Field Populations of Nontarget Immature Lepidoptera, Warm Springs, Oregon

Cooperative Agreement No. PNW 93-0398
Between Willamette Institute for Biological Control
and the US Forest Service

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Term of project:
April 1, 1993 - December 31, 1993

Summary.

The aerial application of *Bacillus thuringiensis kurstaki* for suppression of the spruce budworm on conifers in the Warm Springs Indian Reservation, during 1993, resulted in a significant decline in populations of certain nontarget Lepidoptera. A comparison of treated and untreated sites demonstrated reduced species richness, reduced numbers of caterpillars, and reduced quantity of live caterpillar mass on manzanita, snowbrush, and ocean spray. The degree of reduction varied by parameter and time post-treatment. In general, species richness was initially reduced by 33-67%, numbers of caterpillars were reduced by 72-86%, and live caterpillar mass was reduced by 84-97%.

INTRODUCTION

Large-scale application of *Bacillus thuringiensis* var. *kurstaki* [Btk] is an integral component of current forest pest management programs. The use of Btk avoids many of the nontarget and environmental contamination problems inherent in the use of synthetic pesticides. However, concerns also exist regarding the large-scale application of Btk in woodlands and forests. These concerns focus on the effects of Btk on populations of nontarget Lepidoptera. This is relevant to ecosystem processes because Lepidoptera are important components of certain food webs for other insects, vertebrates, and key to plant growth/competition relationships.

To date, two studies have been conducted on the impact of large-scale Btk applications on field populations of immature Lepidoptera in Oregon (Miller 1990, Miller 1992). Both studies demonstrated a reduction in population density, a reduction in species richness and a period of population recovery/recolonization requiring at least two years. The consequences of these effects on vertebrates that utilize Lepidoptera as food are unknown.

The relationships between bats, Lepidoptera, and Btk-based control programs for the spruce budworm are a current concern to forest management in the Cascade Mountains, Oregon. In 1993 Btk was used for suppression of the spruce budworm occurring on the Warm Springs Indian Reservation. The purpose of this project was to document the impact of Btk on immature Lepidoptera during the conduct of the spruce budworm suppression program. Furthermore, this study adds significantly to the limited database available regarding effects of Btk on nontarget Lepidoptera. The unique site characteristics (i.e., geographic location, floral composition) and the specific procedures employed for suppression of the spruce budworm (i.e., dose and frequency of Btk application) provided the conditions for acquiring data critical to challenging/validating observations of the first two studies. The consistencies and inconsistencies in the specific and the general observations of how Btk impacts Lepidoptera can then be incorporated into an assessment of impacts on vertebrates, such as bats.

OBJECTIVES

The objective of this project was to evaluate the effects of Btk on nontarget immature Lepidoptera. A null and alternate hypothesis are as follows.

Null hypothesis: the use of Btk did not result in significant differences in species abundance between treated and untreated sites.

Alternative hypothesis: the use of Btk resulted in significant differences in species abundance between treated and untreated sites.

The null hypothesis could be rejected if significant differences occurred between sites in species composition described in terms of species richness, abundance of individual caterpillars, or live caterpillar mass. Similarly, the alternative hypothesis could be rejected if no significant differences were observed.

METHODS

The field aspect of this study was conducted from May 15, 1993 to August 27, 1993. The study sites occurred within the southernmost region of the Warm Springs Indian Reservation, Jefferson Co., Oregon. The study was conducted in conjunction with a large scale application of Btk against the spruce budworm.

The impact of Btk was assessed by sampling the immature Lepidoptera associated with three plant species: *Arctostaphylos patula* (manzanita), *Ceanothus velutinus* (snowbrush), and *Holodiscus discolor* (ocean spray). The decision on which plants to sample for immature Lepidoptera considered: 1) physical aspects of the habitat (i.e., slope, canopy, and elevation); 2) size of plants (i.e., height and foliage density); 3) the number of plants within patches of 100 x 100 m.; and 4) previous experience and unpublished documentation of Lepidoptera associated with certain plant species in the Cascade Mountains of Oregon.

Treatment of areas infested with the spruce budworm occurred on June 19-21 and July 3, 1993, at a rate of 24 BIU per acre. Only the sites treated in the June 19-21 treatment are considered here because the July 3 treatment was applied to the area originally designated as a untreated site for this study.

Transects for sampling immature Lepidoptera were located in treated and untreated sites according to plant communities and terrain. The caterpillars associated with the study plants were sampled by shaking foliage above a 75x75 cm sheet for a timed interval of ca. 5 sec. After 5 sec. the sheet was moved to another position and the same sampling technique was repeated. Sampling continued until a total of 360-440 sec of sampling effort was achieved at each site. The data are reported on the basis of 100 sec sampling effort. Thus, the sampling involved shaking foliage above the sheet at 72-88 positions which typically involved 14-22 individual plants. Caterpillars were collected alive, counted, photographed, weighed, and individually reared to adults. Adults were required for accurate identification of the species.

One pretreatment and three post-treatment samples were taken. The pretreatment sample occurred on June 15, 1993. The first post-treatment sample occurred on July 3, 1993, 13 days after application of Btk. The second post-treatment sample occurred on July 30, 1993, 40 days after application of Btk. The third post-treatment sample occurred on August 27, 1993, 68 days after application of Btk.

The samples were assessed to determine abundance and live mass of all immature Lepidoptera. The analysis of data involved a comparison of values before and after the Btk application for each site and between each site by sample date.

Typically, projects such as the present study obtain data that do not conform to the criteria of parametric statistical analysis (see Miller 1990, 1992). Thus, sample data were analyzed using the G-test (Sokal & Rolf, 1980) based on absolute counts regarding the number of

species, abundance, and total weight of caterpillars. This test provides one degree of freedom based on X^2 distribution in a comparison of observed and expected values. For this study the expected values were the average of observed values from the treated and untreated sites. The hypothesis for the G-test regarding the current study was H_o: A = B = 50%. This hypothesis states that samples from treated and untreated sites will exhibit equal valus for either species richness, number of caterpillars, or live caterpillar mass.

RESULTS

The results are presented in the order of sample dates: pretreatment, post-treatment-13 days, post-treatment-40 days, and post-treatment-68 days. Within each sample date the data are organized according to species richness, caterpillar abundance, and live caterpillar mass with reference to each of the three principle plant species (see Fig. 1).

PRETREATMENT

Untreated and to-be-treated sites were similar in species richness, number of individual caterpillars, and live caterpillar mass with only one exception. The exception was a significant difference in live caterpillar mass on *A. patula* (Table 1).

Species richness.

No significant differences were observed in the data regarding species richness in the immature Lepidoptera collected from the three plant species in the to-be-treated and untreated sites.

ARCTOSTAPHYLOS PATLUA. A nonsignificant difference of 8 and 9 species, respectively, occurred between to-be-treated and untreated sites regarding species richness on manzanita.

CEANOTHUS VELUTINUS. A nonsignificant difference of 10 and 13 species, respectively, occurred between to-be-treated and untreated sites regarding species richness on snowbrush.

HOLODISCUS DISCOLOR. A nonsignificant difference of 7 and 9 species, respectively, occurred between to-be-treated and untreated sites regarding species richness on ocean spray.

Caterpillar abundance.

No significant differences were observed in the data regarding the number of caterpillars collected from the three plant species in the to-be-treated and untreated sites.

ARCTOSTAPHYLOS PATLUA. A nonsignificant difference of 11.5 and 14.5, respectively, occurred between to-be-treated and untreated sites regarding the number of caterpillars collected per 100 sec sampling effort on manzanita.

CEANOTHUS VELUTINUS. A nonsignificant difference of 11.8 and 9.5, respectively, occurred between to-be-treated and untreated sites regarding the number of caterpillars collected per 100 sec sampling effort on snowbrush.

HOLODISCUS DISCOLOR. A nonsignificant difference of 32.3 and 36.7, respectively, occurred between to-be-treated and untreated sites regarding the number of caterpillars collected per 100 sec sampling effort on ocean spray.

Total live mass.

Live caterpillar mass on *A. patula* was the only variable demonstrating a significant pretreatment difference between sites.

ARCTOSTAPHYLOS PATLUA. The live caterpillar mass on manzanita in the to-be-treated site was significantly ($G=4.170$, $P<0.05$) lower than in the untreated site, 323 and 377 mg, respectively.

CEANOTHUS VELUTINUS. A nonsignificant difference of 319 and 354 mg, respectively, occurred between to-be-treated and untreated sites regarding the live caterpillar mass collected per 100 sec sampling effort on snowbrush.

HOLODISCUS DISCOLOR. A nonsignificant difference of 917 and 839 mg, respectively, occurred between to-be-treated and untreated sites regarding the live caterpillar mass collected per 100 sec sampling effort on ocean spray.

POST-TREATMENT: 13 days

Effects of the Btk application two weeks after treatment were significant in all but one measurement. The exception was species richness on ocean spray (Table 2).

Species richness.

A significant decline was observed in species richness on two of the three plants sampled.

ARCTOSTAPHYLOS PATLUA. The Btk treatment significantly reduced the number of species of Lepidoptera on manzanita. A comparison of species richness prior to treatment and two weeks post-treatment indicated the number of species in the untreated site increased 67% but dropped 38% in the treated site. Two weeks after treatment the untreated site contained three times as many species: 15 species in the untreated site versus 5 species in the treated site, a significant difference ($G=5.232$, $P<0.025$).

CEANOTHUS VELUTINUS. The Btk treatment significantly reduced the number of species of Lepidoptera on snowbrush. A comparison of species richness prior to treatment and two weeks post-treatment indicated the number of species in the untreated site increased 15% but dropped by 50% in the treated site. Two weeks after treatment the untreated site contained three times as many species: 15 species in the untreated site versus 5 species in the treated site, a significant difference ($G=5.232$, $P<0.025$).

HOLODISCUS DISCOLOR. The Btk treatment did not significantly reduce the number of species of Lepidoptera on ocean spray. A comparison of species richness prior to treatment and two weeks post-treatment indicated the number of species in the untreated site remained the same and only dropped by 33% in the treated site. Two weeks after treatment the untreated site contained only three more species than the treated site.

Caterpillar abundance.

The number of caterpillars collected per 100 sec sampling effort was significantly reduced in the treated site for all three plant species (Table 2).

ARCTOSTAPHYLOS PATLUA. The Btk treatment significantly reduced the number of caterpillars on manzanita. Prior to treatment, the untreated site contained almost twice as many caterpillars as the to-be treated site. However, the number of caterpillars in the untreated site increased 68% two weeks after treatment to 24.4 caterpillars per 100 sec of sample effort and the number of individuals in the treated site declined by 42% to 6.7 caterpillars per 100 sec of sample effort, a significant between site difference ($G=10.703$, $P<0.010$).

CEANOTHUS VELUTINUS. The Btk treatment significantly reduced the number of caterpillars on snowbrush. Prior to treatment, the untreated site and the to-be treated site contained nearly an identical number of caterpillars. However, the number of caterpillars increased 274% in the untreated site two weeks after treatment to 35.6 caterpillars per 100 sec of sample effort. The number of individuals in the treated site declined by 43%, a significant between site difference ($G=21.671$, $P<0.001$).

HOLODISCUS DISCOLOR. The Btk treatment significantly reduced the number of caterpillars on ocean spray. Prior to treatment, the untreated site and the treated site contained similar numbers of caterpillars. Although the number of caterpillars in the untreated site decreased by 25% two weeks after treatment, the number of caterpillars decreased by 88% in the treated site, a significant between site difference ($G=16.499$, $P<0.001$).

Total live mass.

The live caterpillar mass collected per 100 sec sampling effort was significantly reduced in the treated site for all three plant species (Table 2).

ARCTOSTAPHYLOS PATLUA.The Btk treatment significantly reduced the quantity of live caterpillar mass on manzanita. Although the treated site contained a significantly lower live caterpillar mass prior to treatment the difference two weeks after treatment was significantly lower by an increase of a magnitude of two fold. The mass of caterpillars in the untreated site increased 83% two weeks after treatment while the treated site caterpillar mass dropped to 150 mg, a decline of 52%, a significant between site difference ($G=367.064$, $P<0.001$).

CEANOTHUS VELUTINUS. The Btk treatment significantly reduced the quantity of live caterpillar mass on snowbrush. Prior to treatment, the untreated site contained a (nonsignificant) higher amount of caterpillar mass than in the to-be treated site. However, in the untreated site the mass of caterpillars increased 347% two weeks after treatment to 1581 mg of caterpillars per 100 sec of sample effort while in the treated site caterpillar mass dropped by 31%, a significant between site difference ($G=1162.492$, $P<0.001$).

HOLODISCUS DISCOLOR. The Btk treatment significantly reduced the quantity of live caterpillar mass on manzanita. Prior to treatment, the untreated site contained a (nonsignificant) lower mass than in the treated site. Although the mass of caterpillars in the untreated site decreased by 15% to 713 mg of caterpillars per 100 sec of sample effort two weeks after treatment, the mass of caterpillars decreased by 98% in the treated site, a significant between site difference (G=821.203, P<0.001).

POST-TREATMENT: 40 days

Significant reductions in species richness, number of caterpillars, and live caterpillar mass were still noticed six weeks after treatment with Btk, with one exception. The exception was species richness on manzanita. No data for untreated ocean spray are available due to the treatment of the original untreated site (Table 3).

Species richness.

The number of species on manzanita and snowbrush was lower in the treated site but significantly so only on snowbrush.

ARCTOSTAPHYLOS PATLUA. Six weeks after treatment the untreated site contained twice as many species as the treated site: 8 species in the untreated site versus 4 species in the treated site, a nonsignificant difference (G=1.356, P<0.300).

CEANOTHUS VELUTINUS. Six weeks after treatment the untreated site contained nearly three times the number of species as in the treated site: 14 species in the untreated site and 5 species in the treated site, a significant difference (G=4.439, P<0.05).

HOLODISCUS DISCOLOR. Six weeks after treatment the treated site contained only 2 species. No data are available to represent an untreated site.

Caterpillar abundance.

The number of caterpillars was still significantly reduced in the treated sites six weeks after treatment.

ARCTOSTAPHYLOS PATLUA. Six weeks after treatment the untreated site contained 17.3 versus 5.2 caterpillars per 100 sec samplng effort in the treated site, a significant difference (G=6.864, P<0.10).

CEANOTHUS VELUTINUS. Six weeks after treatment the untreated site contained 14.6 versus 3.1 caterpillars per 100 sec sampling effort in the treated site, a significnat difference (G=8.114, P<0.005)

HOLODISCUS DISCOLOR. Six weeks after treatment the treated site contained 0.6 caterpillars per 100 sec sampling effort. No data are available to represent an untreated site.

Total live mass.

Live caterpillar mass was significantly reduced on manzanita and snowbrush in the treated site six weeks after treatment.

ARCTOSTAPHYLOS PATLUA. Six weeks after treatment the untreated site contained 286 mg versus 43 mg in the treated site, a significant difference (G=200.975, P<0.001).

CEANOTHUS VELUTINUS. Six weeks after treatment the untreated site contained 298 mg versus 12 mg in the treated site, a significant difference (G=328.182, P<0.001).

HOLODISCUS DISCOLOR. Six weeks after treatment the treated site contained 19.8 mg of live caterpillar mass. No data are available to represent an untreated site.

POST-TREATMENT: 68 days

Significant reductions in species richness, number of caterpillars, and live caterpillar mass were still noticed ten weeks after treatment with Btk, with no exceptions. No data for untreated ocean spray are available due to the treatment of the original untreated site (Table 4).

Species richness.

ARCTOSTAPHYLOS PATLUA. Ten weeks after the treatment the untreated site contained 5 species while no species were present in the treated site, a significant difference ($G=6.931$, $P<0.010$).

CEANOTHUS VELUTINUS. Ten weeks after the treatment the untreated site contained 11 species while only 3 species were present in the treated site, a significant difference ($G=4.860$, $P < 0.050$).

HOLODISCUS DISCOLOR. Ten weeks after the treatment the treated site contained 1 species. No data are available to represent the untreated site.

Caterpillar abundance.

The number of caterpillars was still significantly reduced in the treated sites ten weeks after treatment.

ARCTOSTAPHYLOS PATLUA. Ten weeks after treatment the untreated site contained 3 caterpillars per 100 sec of sample effort while no larvae were collected in the treated site, a significant difference ($G=4.159$, $P<0.050$).

CEANOTHUS VELUTINUS. Ten weeks after the treatment the untreated site contained 9.2 caterpillars per 100 sec of sample effort while the treated site contained 1.3 caterpillars per 100 sec of sample effort, a significant difference ($G=6.693$, $P<0.020$).

HOLODISCUS DISCOLOR. Ten weeks after the treatment the treated site contained 0.5 caterpillars per 100 sec of sampling effort. No data are available to represent the untreated site.

Total live mass.

Live caterpillar mass was significantly reduced on manzanita and snowbrush in the treated site ten weeks after treatment.

ARCTOSTAPHYLOS PATLUA. Ten weeks after the treatment the untreated site contained 45 mg of caterpillars per 100 sec of sample effort while no larvae were collected in the treated site, a significant difference ($G=62.383$, $P<0.001$).

CEANOTHUS VELUTINUS. Ten weeks after the treatment the untreated site contained 101 mg of caterpillars per 100 sec of sample effort while 19 mg of caterpillars were present in the treated site, a significant difference ($G=61.5$, $P<0.001$).

HOLODISCUS DISCOLOR. Ten weeks after the treatment the untreated site contained 3.0 mg of caterpillar per 100 sec of sampling effort. No data are available to represent the untreated site.

DISCUSSION

If the difference between treated and untreated sites are compared as a ratio, then a value representing percent loss of species, caterpillars and mass may be examined (Fig 1). The seasonal trend in the differences between treated and untreated sites indicated that the Lepidoptera in the treated site, with fewer species, individuals, and mass, was depauperate relative to the untreated site.

The data suggest a rejection of the null hypothesis which stated no differences were expected between treated and untreated sites. Two weeks after treatment with Btk two of the three plant species studied showed that associated caterpillars were subjected to a significant reduction in species richness. All three plant species contained significantly fewer caterpillars. Also, live mass of caterpillars was significantly reduced on all three plant species. The effects of reduced species richness, fewer caterpillars, and lower live caterpillar mass in the Btk treated site were observed to one degree or another through the entire sampling period. These data are consistent with previous results reported from field-based studies on the nontarget effects of Btk on immature Lepidoptera (Miller 1990, Miller 1992).

One of the main purposes of this study was to document the impact of Btk on nontarget Lepidoptera because moths appear to be an important component in the diet of Thompson's long-eared bat. The data regarding caterpillar species richness, abundance, and mass are relevant to speculating about the effects of Btk on the availability of food for the bat because reproductive success expressed as larval survival was significantly reduced. If the bat prefers certain species and those species are part of the 33-67% component of species that were lost in the treated site, then Btk would be expected to have a dramatic impact on the food resources of the bat. If the bat prefers species (including prey other than moths) in the component of species not impacted, then the impact on the food resources of the bat would not be as dramatic but abundance of moths would likely be low and mitigated to some degree by immigration. Similarly, whether or not the bat exhibits preference for moth species, if it is selective for Lepidoptera in general, then the use of Btk would result in a significant reduction in prey abundance resulting in a narrowed selection of prey items for survival of the bat. Lastly, if Lepidoptera provide an efficient source of prey, in the theoretical realm of optimal foraging, then the loss of moths as an integral component of their diet, such as for milk production during nursing of young, would likley force bats to forage longer and further from their roosts.

PROJECTED NEEDS

Questions for further analysis are: Will the community of Lepidoptera in the treated site return to a proportion of species similar to that of pre-treatment conditions? How long does the Lepidoptera community remain in a disrupted state? Which species recover most rapidly and why? How do the variables of time and space concerning

the Btk application influence the degree of impact on the nontarget species? A key concern related to these questions is what the impact of Btk will be on nontarget populations of Lepidoptera that have important functions in food webs of vertebrates, such as the Thompsons long-eared bat. Data relevant to the last mentiuoned concern are inadequate and need to be acquired.

ACKNOWLEDGMENTS

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Table 1.

Pretreatment differences in species richness, number of caterpillars collected per 100 sec sampling effort (beating sheet), and live caterpillar mass (mg) for immature Lepidoptera collected along transects within an untreated site and a site designated to be treated with *Bacillus thuringiensis kurstaki* (24 BIU). Warm Springs Indian Reservation (treated) and the Metolius Basin (untreated), Jefferson Co., Oregon. June 15, 1993.

Plant, Variable[1>]	Treated	Untreated	Treated: Untreated	G-value, P	
Arctostaphylos patula					
Species	8	9	0.89	0.069	0.80
Individuals	11.5	14.5	0.79	0.347	0.70
Live mass*	323	377	0.86	4.170	0.05
Ceanothus velutinus					
Species	10	13	0.77	0.392	0.70
Individuals	11.8	9.5	1.24	0.249	0.70
Live mass	319	354	0.91	1.821	0.20
Holodiscus discolor					
Species	7	9	0.78	0.251	0.70
Individuals	32.3	36.7	0.88	0.281	0.70
Live mass	917	839	1.09	3.466	0.10

1> * denotes significant differences between treated and untreated sites at a probability of at least $P<0.05$.

Table 2.

Differences 13 days post treatment in species richness, number of caterpillars collected per 100 sec sampling effort (beating sheet), and live caterpillar mass (mg) for immature Lepidoptera collected along transects within an untreated site and a site treated with *Bacillus thuringiensis kurstaki* (24 BIU). Warm Springs Indian Reservation (treated) and the Metolius Basin (untreated), Jefferson Co., Oregon. July 3, 1993.

Plant, Variable[1>]	Treated	Untreated	Treated: Untreated	G-value, P	
Arctostaphylos patula					
Species*	5	15	0.33	5.232	0.025
Individuals*	6.7	24.4	0.28	10.703	0.010
Live mass*	154	689	0.12	367.064	0.001
Ceanothus velutinus					
Species*	5	15	0.33	5.232	0.025
Individuals*	6.7	35.6	0.19	21.671	0.001
Live mass*	219	1581	0.14	1162.492	0.001
Holodiscus discolor					
Species	6	9	0.67	0.604	0.500
Individuals*	4	24.6	0.16	16.499	0.001
Live mass*	22	713	0.03	821.203	0.001

[1>] * denotes significant differences between treated and untreated sites at a probability of at least $P<0.05$.

Table 3.

Differences 40 days post treatment in species richness, number of caterpillars collected per 100 sec sampling effort (beating sheet), and live caterpillar mass (mg) for immature Lepidoptera collected along transects within an untreated site and a site treated with *Bacillus thuringiensis kurstaki* (24 BIU). Warm Springs Indian Reservation (treated) and the Metolius Basin (untreated), Jefferson Co., Oregon. July 30, 1993.

Plant, Variable[1>]	Treated	Untreated	Treated: Untreated	G-value, P	
Arctostaphylos patula					
Species	4	8	0.50	1.359	0.300
Individuals*	5.2	17.3	0.30	6.864	0.010
Live mass*	43	286	0.15	200.975	0.001
Ceanothus velutinus					
Species*	5	14	0.36	4.439	0.050
Individuals*	3.1	14.6	0.21	8.114	0.005
Live mass*	12	298	0.04	328.182	0.001
Holodiscus discolor					
Species	2	X	X	X	X
Individuals	0.6	X	X	X	X
Live mass	19.8	X	X	X	X

1> * denotes significant differences between treated and untreated sites at a probability of at least $P<0.05$.

Table 4.

Differences 68 days post treatment in species richness, number of caterpillars collected per 100 sec sampling effort (beating sheet), and live caterpillar mass (mg) for immature Lepidoptera collected along transects within an untreated site and a site treated with *Bacillus thuringiensis kurstaki* (24 BIU). Warm Springs Indian Reservation (treated) and the Metolius Basin (untreated), Jefferson Co., Oregon. August 27, 1993.

Plant, Variable[1]	Treated	Untreated	Treated: Untreated	G-value, P	
Arctostaphylos patula					
Species*	0	5	0.00	6.931	0.010
Individuals*	0	3	0.00	4.159	0.050
Live mass*	0	45	0.00	62.383	0.001
Ceanothus velutinus					
Species*	3	11	0.27	4.860	0.050
Individuals*	1.3	9.2	0.14	6.693	0.020
Live mass*	19	101	0.19	61.500	0.001
Holodiscus discolor					
Species	1	X	X	X	X
Individuals	0.5	X	X	X	X
Live mass	3	X	X	X	X

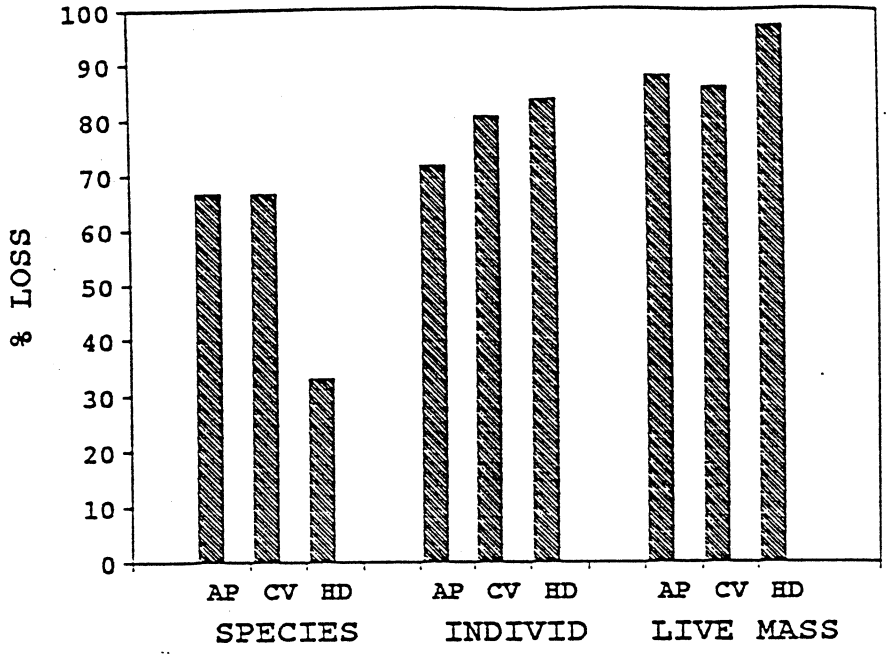
[1] * denotes significant differences between treated and untreated sites at a probability of at least $P<0.05$.

Figure Legend:

Fig. 1.

A comparison expressed as percent loss [(treated:untreated)x100] of the number of species, individual caterpillars, and live caterpillar mass collected: A) Post-treatment - 13 days; B) Post-treatment - 40 days; and C) Post-treatment - 68 days. The plants sampled were: *Arctostaphylos patula* [AP], *Ceanothus velutinus* [CV], and *Holodiscus discolor* [HD] along two transects. One transect consisted of samples from untreated plants while the other transect occurred in an area treated with *Bacillus thuringiensis kurstaki* (24 BIU). Warm Springs Indian Reservation (treated) and Metolius Basin (untreated), Jefferson Co., Oregon, 1993.

A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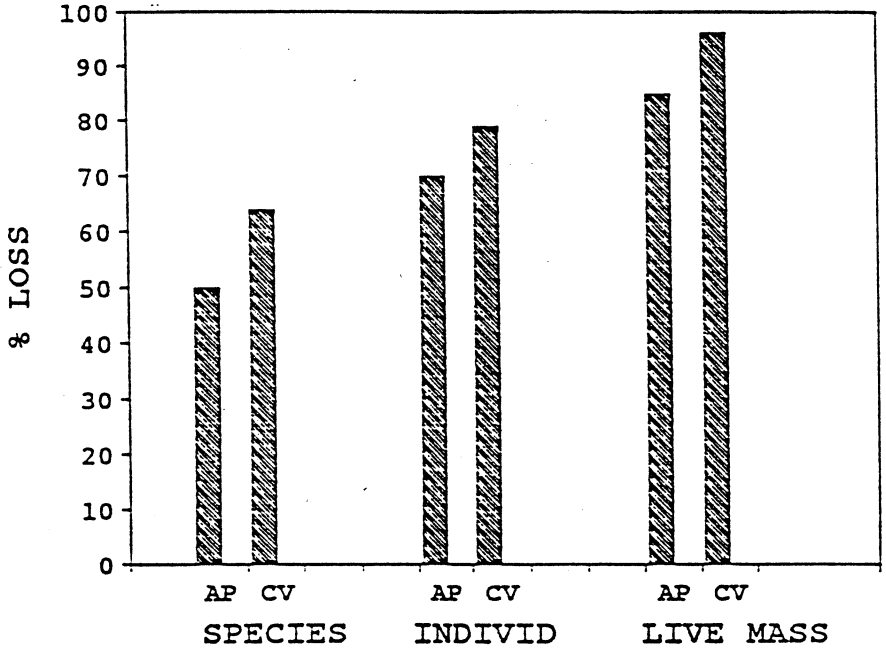
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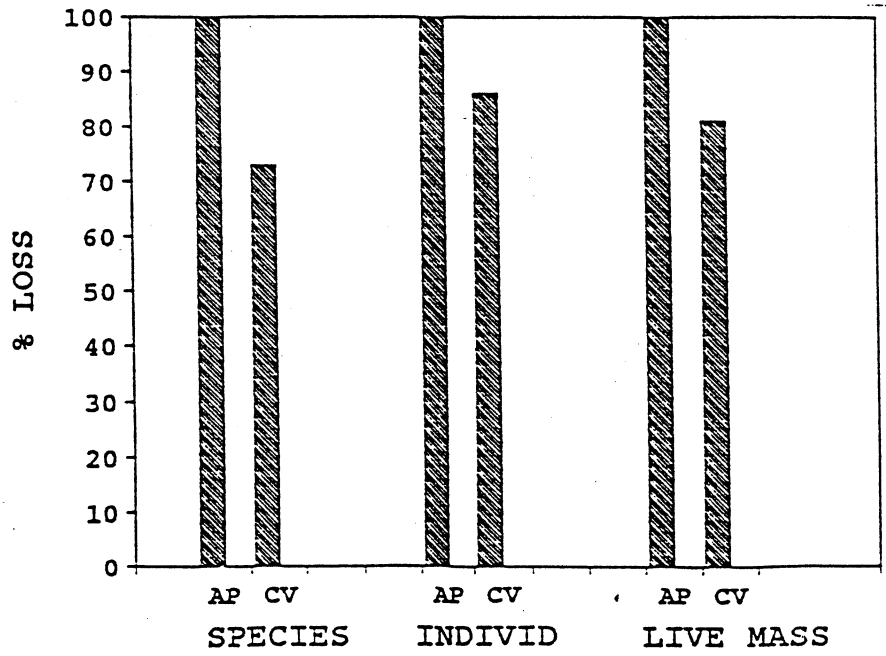
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